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UTILIZATION OF WASTE FOR ENHANCEMENT OF BIOGAS PRODUCTION

SHIKHA MEHTA[1], R.C. ANAND[2], KAMLA MALIK[3], NAVEEN KUMAR[4] & SUJEETA[5]

[1,2,3,5] Department of Microbiology, College of Basic Sciences and Humanities,

Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

[4]Department of Farm Machinery and Power Engineering, College of Agriculture Engineering and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India

ABSTRACT

Anaerobic digestion of cattle dung and other household, industrial and agricultural wastes leads to the production of biogas. It is one of the most effective and economic way for the production of bio-energy from biomass. In the present investigation, compost, paddy soil, landfill waste and kitchen waste were used to develop the microbial inoculum for the enhancement of biogas production from cattle dung under semi-continuous digestion system. Fourteen digesters were set up. The samples were analyzed for dehydrogenase activity, cellulase activity, N, P, K content, total solids, volatile solids, total volatile fatty acids, carbon to nitrogen ratio and biogas production. The maximum biogas production (144.2 litres) was observed on supplementation of cattle dung with kitchen waste @ 5%, compost @ 5%, landfill waste @ 5% and paddy soil @ 5% on dry weight basis in semi-continuous anaerobic digestion. The dehydrogenase activity (1993.0 µg TPF/g sample/24 h) and cellulase activity (259.4 µg glucose/g sample/24 h) was observed at 8th week in digester D14. Total volatile fatty acids, total solids and volatile solids were found to decrease after 8 weeks of digestion. N, P and K content was found to increase whereas C/N ratio was found to decrease.

KEYWORDS: Biogas, Anaerobic Digestion, Biomass & Fertilizer

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INTRODUCTION

The ever increasing cost of fossil fuels and the pollution caused by these has provided the pedigree to consider alternative sources of energy. Biogas is a well established fuel that can supplement as an energy source for cooking and lighting purposes in developing countries. Biogas is produced by anaerobic degradation of organic matter and it is a mixture of gases. It consists of 50-75% methane, 20-50% CO_2, 0-10% N_2, 0-1% H_2, 0-3% H_2S and 0-0.5% O_2. The conversion of organic matters into biogas can be divided in three stages: hydrolysis, acid formation, and methane production. In these different stages which are however carried out in parallel, different groups of bacteria collaborate by forming an anaerobic food chain where the products of one group will be the substrates of another group (Horvath *et al.*, 2016). A wide variety of microbial communities have been reported to be involved in the anaerobic digestion process. Lee *et al.* (2009) reported that *Clostridium* species are most common among the degraders under anaerobic conditions. However, anaerobic degradation of organic matter does not rely on a single microbial strain and generally a microbial consortium is responsible for the anaerobic digestion process (Fantozzi and Buratti, 2009). According to Ike *et al.* (2010), a group of microorganisms such as *actinomyces*, *Thermomonospora*, *Ralstonia* and *Shewanella* are involved in the degradation of food waste into volatile fatty acids, but *Methanosarcina* and *Methanobrevibacter/ Methanobacterium* mainly contribute in methane production. Charles *et al.* (2009) reported the presence of *Methanosarcina thermophila*, *Methanoculleus*

thermophilus, and *Methanobacterium formicicum* during anaerobic digestion. The production of biogas from organic waste depends upon several factors such as temperature, pH, retention time etc. but one of the most important factor which affects the anaerobic degradation process is temperature. The operation in the mesophilic range is more stable and requires a smaller energy expense. Ward *et al.* (2008) has shown optimal growth temperatures for some methanogenic bacteria: 37-45^{o}C for mesophilic *Methanobacterium*, 37-40^{o}C for *Methanobrevibacter*, 35-40^{o}C for *Methanolobus*, *Methanococcus*, *Methanoculleus*, *Methanospirillum* and *Methanolobus* and 30-40^{o}C for *Methanoplanus* and *Methanocorpusculum*. Since, biogas production is carried out by a consortium of microorganisms and depends on various factors like pH, temperature, HRT, C/N ratio, etc., it is a relatively slow process. The decrease in gas generation during winter season has been reported which poses a serious problem in the practical application of this technology. Several methods have been reported to increase the efficiency of biogas production, for example, optimizing the various operational parameters, satisfying the nutritional requirements of microbes, using different biological and chemical additives and manipulating the feed proportions (Satyanarayan and Shivayogi, 2010; Wei *et al*., 2010). The purpose of this study was to find out how the kitchen waste, landfill waste, paddy soil and compost could be converted into biogas. The choice of these substrates was due to the fact that they are the most commonly generated wastes.

MATERIALS AND METHODS

Anaerobic Semi-Continuous Digestion

For determining the effect of kitchen waste, compost, landfill waste and paddy soil on biogas production, various combinations of these substrates were made and then fed into aspirator bottles of 5 litre capacity.

Following fourteen digesters were set up for determining the effect of these wastes on biogas production:

(D1). Cattle dung (CD) + biogas slurry @ 10%

(D2). CD + biogas slurry @ 20%

(D3). CD + compost @10%

(D4). CD + landfill waste @ 10%

(D5). CD + paddy soil @ 10%

(D6). CD + compost @ 5% + landfill waste @ 5%

(D7). CD + compost @ 5% + paddy soil @ 5%

(D8). CD + landfill waste @ 5% + paddy soil @ 5%

(D9). CD + compost @ 5% + landfill waste @ 5% + paddy soil @ 5%

(D10). CD + kitchen waste @ 10%

(D11). CD + kitchen waste @ 5% + landfill waste @ 5%

(D12). CD + kitchen waste @ 5% + paddy soil @ 5%

(D13). CD + kitchen waste @ 5% + compost @ 5%

(D14). CD + kitchen waste @ 5% + compost @ 5% + landfill waste @ 5%, + paddy soil @ 5%

Analysis of Influent and Effluent Slurry

The influent and effluent slurry was analyzed for various parameters such as pH, total solids, volatile solids, organic carbon content, total volatile fatty acids, cellulose, hemicellulose and lignin contents (AOAC, 2000).

The samples were analyzed for dehydrogenase activity, cellulase activity, nitrogen, phosphorous and potassium content using the procedures of Casida *et al.*,1964; Deng and Tabatabai, 1994; Bremner,1965; John,1970 and Antil *et al.*, 2002, respectively. The rate of biogas production was estimated by water displacement method.

RESULTS AND DISCUSSIONS

To assess the effect of kitchen waste, compost, landfill waste and paddy soil on biogas production, various combinations of these inocula with cattle dung were made for the enrichment of microflora and digestion was carried out in semi-continuous manner for eight weeks.

The influents of various digestion times were analyzed for various parameters. Weekly changes in pH were recorded and it ranged from 7.27 to 7.90 in digesters D1 to D14. The TVFA ranged from 195 to 300 mg/kg. Total solid content was in the range of 15.72 to 23.43 %. Volatile solids ranged between 78.5 to 89.0 (% of TS) (Table-1). The Nitrogen content ranged between 1.28 to 1.44 %. C/N ratio was in the range of 31.5 to 38.7. Cellulose and hemicellulose content ranged between 32.1 to 35.8 and 17.9 to 20.5% respectively. Lignin content was in the range of 9.1 to 11.5%. The Phosphorus content was highest in digester, D13 (0.59%) and potassium content was highest in digester, D14 (1.30%) (Table-2).

The biogas production was recorded for eight weeks in semi-continuous digestion. The temperature ranged from 32.0 to 37.1˚C during eight weeks. The total biogas production increased in eight weeks of incubation by supplementation of cattle dung with these inocula. The cumulative biogas production in digester -1 was 121.3 litres in eight weeks which increased to 144.2 litres on addition of compost, landfill waste, paddy soil and kitchen waste collectively followed by digester, D2 containing 20% inocula of biogas slurry (Figure 1). Soom *et al.,* 2016 observed highest yield of biogas by piggery feaces (1.07 l/kg), followed by cattle dung (0.71 l/kg) with poultry waste the least (0.42 l/kg) all under direct sunlight.

Table 1: Chemical Composition and pH of Influent under Semi-Continuous Digestion

Digesters	pH	TVFA (mg/kg)	Total Solids %	VS (% of TS)	Cellulose (% of TS)	Hemicellulose (% of TS)	Lignin (% of TS)
D1(Control)	7.60	285	22.82	89.0	32.9	18.5	10.6
D2	7.49	255	19.85	88.0	32.1	17.9	10.5
D3	7.46	240	18.28	89.0	33.4	19.3	9.9
D4	7.27	195	16.55	84.0	34.3	20.1	10.2
D5	7.90	225	15.72	84.0	35.8	20.5	9.5
D6	7.74	255	16.04	84.0	34.7	20.3	11.1
D7	7.79	240	15.92	85.0	34.9	19.4	10.0
D8	7.38	180	18.16	84.0	32.7	18.9	11.2
D9	7.55	210	21.21	82.0	33.5	19.3	9.4
D10	7.77	270	19.66	87.0	35.4	18.5	9.1
D11	7.46	270	17.26	83.0	34.3	19.9	10.6
D12	7.51	300	20.27	78.5	34.7	20.1	11.5
D13	7.71	240	19.16	85.0	33.9	19.7	11.1
D14	7.83	210	23.43	85.0	34.4	19.2	10.2

TVFA: Total volatile fatty acids, TS: Total solids, C/N: Carbon/ Nitrogen Ratio

Table 2: Chemical Composition of Influent for N, P and K under Semi-Continuous Digestion

Digesters	Nitrogen (% of TS)	Phosphorus (% of TS)	Potassium (% of TS)	Organic Carbon %	C/N Ratio
D1(Control)	1.33	0.40	1.29	51.6	38.7
D2	1.42	0.46	1.38	51.0	35.9
D3	1.40	0.43	1.32	51.6	36.8
D4	1.28	0.51	1.24	48.7	38.0
D5	1.38	0.46	1.07	48.7	35.2
D6	1.40	0.45	1.11	48.7	34.7
D7	1.31	0.53	1.09	49.3	37.6
D8	1.38	0.51	1.14	48.7	35.2
D9	1.38	0.55	1.12	47.5	34.4
D10	1.41	0.49	1.18	50.4	35.7
D11	1.42	0.37	1.12	48.1	33.8
D12	1.44	0.50	1.15	45.5	31.5
D13	1.39	0.59	1.23	49.3	35.4
D14	1.43	0.50	1.30	49.3	34.4

After completion of semi-continuous digestion for eight weeks, the samples were withdrawn and analyzed for various parameters. The pH was found to increase after eight weeks of digestion. The final pH of 8.29, 8.35, 8.05, 8.07, 8.19, 8.32, 8.35, 8.44, 8.29, 8.19, 8.23, 8.52, 8.14 and 8.15 was observed in digesters 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14 respectively. The Total volatile fatty acids (TVFA) decreased from 285 to 105, 255 to 60, 240 to 75, 195 to 90, 225 to 105 and 255 to 135, 240 to 135, 180 to 75, 210 to 120, 270 to 75, 270 to 120, 300 to 90, 240 to 90 and 210 to 105 mg/kg in digester 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14, respectively. Decrease in TS and VS (% of TS) was observed in all the digesters (Table-3). The Nitrogen, phosphorus and potassium content after digestion increased in effluent as compared to influent. Cellulose, hemicellulose and lignin content decreased after completion of digestion. (Table-4). The maximum degradation (60.8%) of total solids was observed in digester-14 (Cattle dung (3kg) + kitchen waste @ 5%+ compost @ 5% + landfill waste @ 5%+ paddy soil @ 5%) and minimum degradation (29.0%) was in digester-5 (CD + paddy soil @ 10%). The same trend was observed for volatile solids degradation and maximum degradation (16.4%) was observed in digester-14 (Cattle dung (3kg) + kitchen waste @ 5%+ compost @ 5% + landfill waste @ 5%+ paddy soil @ 5%) and minimum degradation of 11.9% was observed in digester, D5 containing paddy soil as an enrichment supplement for microflora (Figure 2). Degradation of total solids and volatile solids could be explained due to breakdown of substrates resulting in production of biogas. A similar observation was reported by Shivaraj and Seenayya (1994) during methanogenesis of poultry waste slurry.

Table 3: Chemical Composition and pH of Effluent after Eight Weeks of Semi-Continuous Digestion

Digesters	pH	TVFA (mg/kg)	Total Solids %	VS (% of TS)	Cellulose (% of TS)	Hemicellulose (% of TS)	Lignin (% of TS)
D1(Control)	8.29	105	12.90	77.0	30.2	17.4	10.4
D2	8.35	060	9.56	74.0	29.9	13.3	10.1
D3	8.05	075	9.43	77.0	31.4	18.5	9.6
D4	8.07	090	9.15	72.0	31.8	17.7	9.8
D5	8.19	105	11.15	74.0	32.5	18.6	8.7
D6	8.32	135	8.71	72.0	32.7	17.9	10.2
D7	8.35	135	10.28	73.0	32.0	18.0	9.7
D8	8.44	075	10.01	73.0	31.3	17.8	10.5
D9	8.29	120	10.63	71.0	31.1	18.6	8.9
D10	8.19	075	10.16	75.0	32.4	17.3	8.3
D11	8.23	120	9.56	73.0	32.1	18.1	9.2

Table 3: Contd.,							
D12	8.52	090	10.34	69.0	31.6	18.8	10.5
D13	8.14	090	10.50	73.0	30.1	17.5	10.3
D14	8.15	105	8.00	71.0	30.2	14.7	8.3

Table 4: Chemical Composition of Effluent for N, P and K after Eight Weeks of Semi-Continuous Digestion

Digesters	Nitrogen (% of TS)	Phosphorus (% of TS)	Potassium (% of TS)	Organic Carbon %	C/N Ratio
D1(Control)	1.39	0.68	1.36	44.6	32.0
D2	1.49	0.77	1.42	42.9	28.7
D3	1.48	0.69	1.41	44.6	30.1
D4	1.37	0.60	1.37	41.7	30.4
D5	1.42	0.64	1.19	42.9	30.2
D6	1.41	0.57	1.20	41.7	29.5
D7	1.37	0.58	1.21	42.3	30.8
D8	1.42	0.62	1.23	42.3	29.7
D9	1.40	0.87	1.27	41.2	29.4
D10	1.43	0.74	1.33	43.5	30.4
D11	1.45	0.72	1.28	42.3	29.1
D12	1.44	0.70	1.22	40.0	27.7
D13	1.40	0.78	1.31	42.3	30.2
D14	1.51	0.73	1.43	41.2	27.2
C.D.	0.014	0.028	0.030	-	-

C.D. - Critical Difference

Microbial biomass in terms of dehydrogenase and cellulase activity was also determined at 15 days interval for eight weeks during semi-continuous digestion. The dehydrogenase and cellulase activity was found to increase upto 8th week of semi-continuous digestion in all the digesters. The minimum dehydrogenase activity (1254 µg TPF/g sample/24 h) was in digester, D5 where paddy soil was used as an inoculum for enriching the cattle dung. On the other hand, it was maximum in the digester, D14 where different amendments such as kitchen waste, compost, landfill waste and paddy soil were made (Table 5). Similarly, the maximum cellulase activity (259.4 µg glucose/g sample/24 h) was in digester, D14 and minimum cellulase activity (172.8 µg glucose/g sample/24 h) was observed in digester, D5 (Table 6).

Table 5: Dehydrogenase Activity during Semi-Continuous Digestion

Digester	Dehydrogenase Activity (µg TPF/g Sample/24 h) Incubation Period (Weeks)				
	0 Week	2nd Week	4th Week	6th Week	8th Week
D1	1473	1543	1681	1724	1938
D2	1476	1542	1627	1707	1976
D3	1342	1421	1685	1876	1944
D4	1272	1348	1487	1915	1919
D5	1254	1382	1404	1447	1469
D6	1529	1627	1643	1717	1932
D7	1502	1594	1652	1703	1959
D8	1429	1482	1599	1602	1884
D9	1378	1445	1613	1749	1924
D10	1509	1631	1662	1815	1947
D11	1468	1483	1564	1702	1981
D12	1469	1573	1582	1596	1978
D13	1468	1585	1694	1812	1939
D14	1606	1642	1675	1724	1993

Table 6: Cellulase Activity During Semi-Continuous Digestion

Digester	Cellulase Activity (µg Glucose/g Sample/24 h)				
	Incubation Period (Weeks)				
	0 Week	2nd Week	4th Week	6th Week	8th Week
D1	195.4	204.7	213.8	229.3	232.5
D2	199.7	213.5	219.3	231.7	237.0
D3	181.4	194.3	201.5	207.0	213.3
D4	175.9	181.6	185.4	195.1	205.7
D5	151.3	158.4	169.7	165.5	172.8
D6	158.2	163.7	170.9	175.0	179.7
D7	160.0	165.1	169.5	173.9	178.4
D8	156.4	159.7	167.1	163.6	173.5
D9	161.7	185.3	192.7	203.7	210.9
D10	170.3	174.2	185.2	192.3	198.3
D11	152.2	158.1	167.3	169.4	175.8
D12	147.8	152.4	162.8	165.2	168.2
D13	158.6	165.2	171.0	176.8	181.1
D14	204.6	218.5	225.9	247.0	259.4

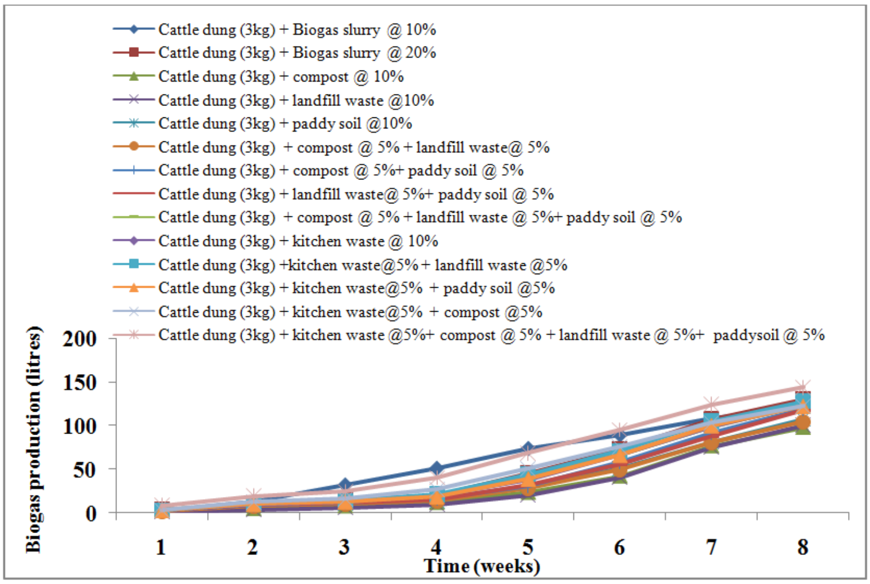

Figure 1: Cumulative Biogas Production from Cattle Dung Supplemented with Combination of Different Inocula during Semi-Continuous Digestion

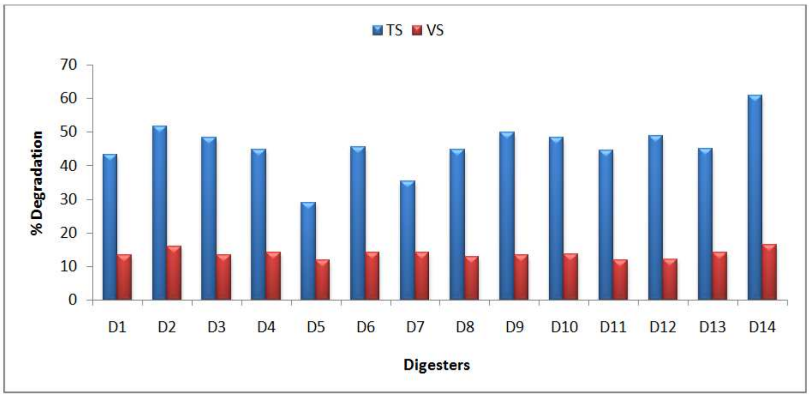

Figure 2: Degradation of Total Solids and Volatile Solids during Semi-Continuous Digestion

CONCLUSIONS

The results of this study have shown clearly that kitchen waste, landfill waste, compost and paddy soil alongwith cattle dung improve the biogas production quantitatively. However, supplementation of paddy soil to cattle dung should be avoided as no increase in biogas production has been achieved after supplementation of paddy soil to cattle dung.

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